REFURBISHMENT OF AN EVENT CENTRE – HOW BUILDING SIMULATION WAS USED TO FORMULATE SOME FUNDAMENTAL DESIGN GUIDELINES FOR AN ARCHITECTURAL COMPETITION

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ABSTRACT

This paper describes the investigation of a former sports centre in order to establish design guidelines for a refurbishment. We performed dynamic thermal and hygrothermal simulations to determine the preference of interior or exterior insulation .

The results of our investigation were integrated in the programme for a competition held in spring 2013.

INTRODUCTION

The “St. Jakob Halle” in Basle, Switzerland, was planned and built in 1974 as a sports centre with several halls. There is a main building with the big hall, which is surrounded by smaller halls and adjacent buildings. Today the building is used for different events, such as sports, concerts, exhibitions and economic forums.

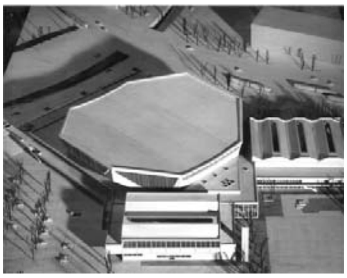


Figure 1 St. Jakob Halle

Our investigations focus on the dynamic thermal behaviour of the main hall, where unoccupied periods alternate with events of 500 up to a maximum of 8700 visitors. The hall and the building services do not fulfil the requirements of thermal comfort and specific aspects linked with the organization of events. The building services do not provide an active cooling system.

The building is structurally sound. Moreover the authority of building and monument conservation showed it´s interest in maintaining the existing structure and shape. Therefore it is planned to insulate the envelope and to replace the building equipment and appliances.

In order to find an attractive architectural solution for the building refurbishment the municipality of Basle will organise a two-phase competition starting in autumn 2012 up to May 2013. To give some important guidelines for the design process we were asked as a consultancy firm to investigate the following questions:

- Will the hall consume more energy (for heating and cooling) with an interior or an exterior insulation?
- Considering building physics what are the consequences of an interior insulation compared to an exterior insulation?

After the winning team is selected, the next step will be to test the feasability of the prize winning solution: this will comprise the analysis of the actual state of the conctrete (e.g.cracks, reinforcement bar corrosion). These findings will influence the final solution for the refurbishment of the building shell. They are not part of this paper.

SIMULATIONS

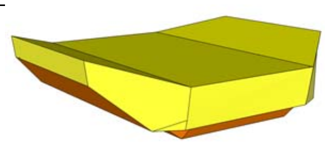
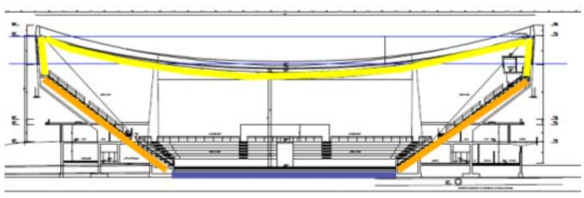
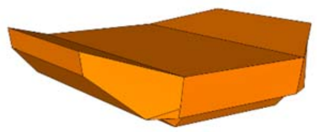
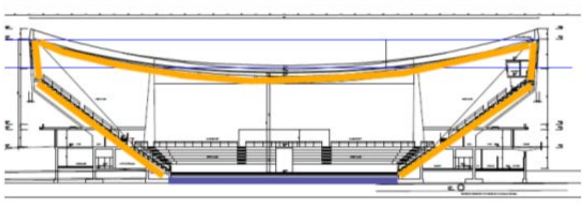
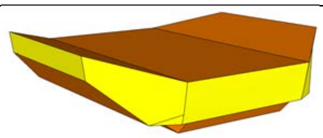
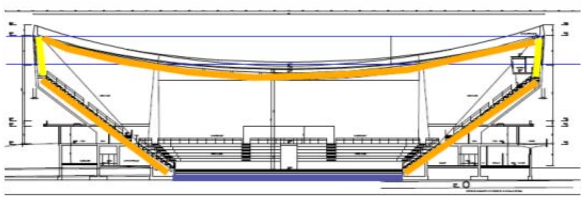
Thermal simulations

To investigate the energy consumption for heating and cooling of the hall we completed a thermal simulation using ESP-r (Clarke, 2001).

The building envelope was insulated in the folowing ways:

- Layout A:
  The roof and aproximately 60% of the wall feature interior insulation. Only the wall with stands has an exterior insulation. The floor is not insulated.
- Layout B:
  The roof an all walls are insulated on the outer face of the construction. The floor is not insulated.
- Layout C:
  The roof provides constructional difficulties for interior insulation (overhead suspensions of sound and lighting equipment). Hence an additional layout featuring roof insulation on the outer face and wall insulation on the interior surface is investigated in order to determine and compare the energy consumption for this compromise solution.

Table 1
Summary of the investigated layouts

Layout A right side: 3D simulation model below: profile	
	
Layout B right side: 3D simulation model below: profile	
	
Layout C right side: 3D simulation model below: profile	
	
legend: Yellow = interior insulation, orange = exterior insulation, purple = no insulation	

We considered different occupancy schedules in summer and winter according to the definitions of the event management. Internal loads for lighting were calculated according to swiss building standards (SIA 2024. 2007). As climate data we usend a typical year for Basel-Binningen, CH, DRY (SIA 2028. 2010).

Simulations considering moisture behaviour of construction elements

To define the composition of the interior insulation we performed a hygrothermal analysis by computer simulations using WUFI (Künzel. 1994; Künzel. 2006). One of the main features of the simulation program is the consideration of wind-driven rain as well as the moisture production of the visitors (EN 15026. 2007; WTA 6-1-01/D, 2002, WTA 6-2-01/D. 2002). The simulation period of the hygrothermal analysis is usually as long as the moisture behaviour of the building has settled (e.g. 10 years).

To compare the consequences of an interior with an exterior insulation we investigated first the most important thermal bridges in the area of windows. The calculation of the steady state heat transfer was performed with TRISCO (EN ISO 10077-2. 2003; EN ISO 10211.2007). To compare the dew point temperature with the relative humidity the moisture production of the visitors was taken into account. To investigate an average situation the outdoor temperature was defined to 0°C with 80% relative humidity (indoor temperature 20°).

OTHER INVESTIGATIONS

Building services

To examine this issue we cooperated with an technical engineer to show which parts of the building services should be replaced.

DISCUSSION AND RESULT ANALYSIS

Findings of the thermal simulation

Figure 2 shows the temperatures during the coldest week in winter. Without heating, indoor temperature is about 1K higher for layout B (exterior insulation) than for layout A (interior insulation). That's because in the case of exterior insulation thermal energy can be stored in the concrete walls.

As shown in table 2, less energy is needed for heating for both occupancy schedules for layout A than for layout B. The compromise solution of layout C is still less energy demanding, even if the large surface of the roof is insulated on exterior face.

In spite of the thermal loads of the people, more heating energy is needed for events with 8700 people. This is caused by the higher air change rate due to a higher occupation rate.

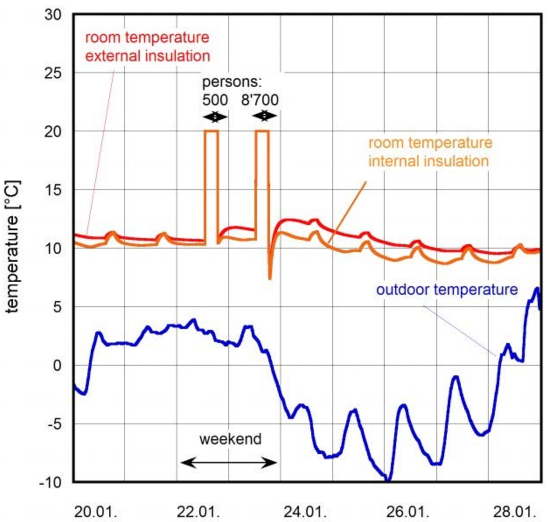


Figure 2 Temperatures in winter, coldest week from 20.01-28.01.

During summer the existing building is not mechanically cooled. However, during events the indoor temperatures are getting up to 32°C (see Figure 3). With an exterior insulation the temperature is always lower than with an interior insulation. This is caused by the buffering effect of the concrete parts of the envelope. For events with 8700 guests, indoor temperature stays even 4 K lower for layout B than for layout A (interior insulation), (see Figure 3).
In order to maintain a max. temperature of 26.5°C (requested by SIA 382/1:2007) the building needs to be cooled in both cases. In doing so more energy is used for layout A than for layout B. Despite of the interior insulation of the walls in layout C, cooling power is still less important than for layout A (interior insulation).

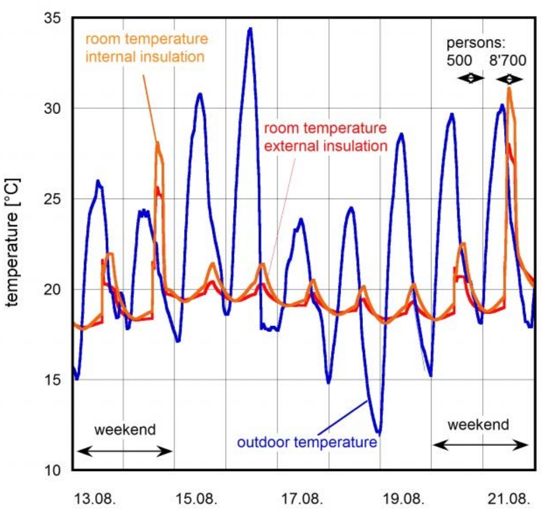
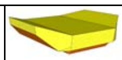
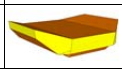


Figure 3 Temperatures in summer, warmest week from 13.08-21.08.

Altogether the net energy demand is bigger for heating than for cooling. This is also true if we take into consideration that the cooling is provided by electrical energy. Concerning the aspect of energy consumption the decision for an interior or exterior insulation depends if there are significantly more events in summer than in winter.

Table 2
Results of the thermal simulation

Layout		People	Heating power [W/m^2]	Cooling power [W/m^2]
A		500	79	-
		8700	292	82
B		500	126	-
		8700	300	48
C		500	119	-
		8700	286	58

Findings of the simulation considering moisture behaviour of construction elements

Hygrothermal Analysis (WUFI)

Figure 4 shows the composition of the interior insulation and how it behaves during a simulation period of 10 years. The red area shows the temperature range, the green area indicates the relative humidity and the blue the moisture content within the building component.

Table 3
Building component with interior insulation from outside to inside

MATERIAL	THICKNESS
Concrete	20 cm
Mortar (system)	1 cm
Capillary-active mineral-based insulation	10 cm
Mortar (system)	1 cm
Mineral wool, substructure	8 cm
OSB-panel (airtight bonding)	2.5 cm
plasterboard	2.25 cm

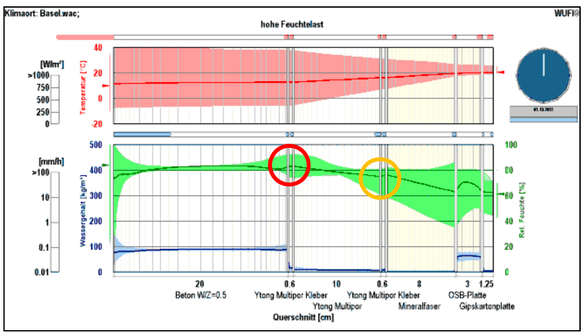


Figure 4 Film display of the cross section distributions of temperature, relative humidity, and moisture content within the layers oft the building component. Left the concrete layer, right interior insulation

Critical areas within the construcion are circled. The read circle indicates the inside face of the conctrete wall, where the relative humidity stays under 95%. This means that frost damage doesn't occur. However, heating pipes within the concrete wall may freeze.

In order to avoid mould fungus at the inside face of the mineral wool (yellow circle) a maximal relative humidity of 80% is to maintain at this point of the assembly.

The moisture behaviour of the investigated construction element will not cause any damages. Though, the quality of workmanship will influence the mould growth risk within the wall.

A construction element with exterior insulation has not been simulated as elements with exterior insulation are largely known as fully functional.

Thermal bridges (TRISCO)

Unsurprisingly, during events in winter condensation appears on the single pane windows due to air humidity caused by the high occupancy of the hall and the activity level.

For the existing thermal bridges the surface temperature is 9.1°C (outdoor temperature 0°C, relative humidity 80%). Relative humidity inside should be under 49% to avoid condensation on the existing construction. Provided that the building envelope is insulated appropriate to (SIA 380/1.2009), the relative humidity may be higher:

- Minimal surface temperature with interior insulation: 17.6°C, condensate at > 86% relative humidity
- Minimal surface temperature with exterior insulation: 17.7°C, condensate at > 87% relative humidity

These high limits of relative humidity seem to allow most of the events to be held without condensation in the area of the window. Some events with the maximum allowed number of 8700 guests could represent exceptions.

Table 4 shows the dampness-production by the respiration and transpiration of people during an event based on (SIA 180.1999). We assume 8700 persons, an air change rate of 1.8 1/h, and a dampness-production of 35/g/pers/h. When condensation appears already after 2 hours of an event for the existing situation, no condensation occurs during the first 6 hours of an event for both insulation types on an average winter day.

Table 4
Relative humidity during an event (outdoor temperature 0°C, relative humidity 80%, internal temperature 20°C

TIME OF EVENT	RELATIVE HUMIDITY INTERIOR [%]
1 hour	32
2 hours	42
3 hours	52
4 hours	62
5 hours	72
6 hours	82

CONCLUSION

From point of energy consumption an interior insulation is better during winter-time, an exterior insulation is more advantageous in summer. However, the compromise solution of interior insulation on the walls and exterior insulation on the roof shows advantages for the winter and summer period: In winter less heating energy is needed than for the case of exterior insulation, in summer less cooling energy is needed than for the case of interior insulation.

Concerning moisture behaviour we could show that carrying out an interior insulation is possible. Even though no protection layer for wind-driven rain exists on the exterior surface of the wall and even if the high humidity levels of ambient air due to a high occupation level are considered, moisture behaviour of the construction element with interior insulation stays within tolerable limits.

The calculations of the thermal bridges and the moisture production during events with 8700 persons show that during the first 6 hours there will be no condensate (for both insulation types).

Hence a clear design guideline for the competition can be given: The walls should be insulated on the interior surface and the roof should get an exterior insulation.

These findings can not be generalized, because the building, it's use and condition are quite special.

OUTLOOK

Our investigation itself and the key results were integrated in the competition programme.

In our presentation we will present some of the results of the competition. At this point this is not possible, as competitions will be completed only by May 2013. It is planned to conclude by presenting in greater detail the specific impact of the findings from dynamic simulations on the results of the competition.

ACKNOWLEDGEMENT

We express our appreciation to the municipality of Basle, CH who assigned the investigation.

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